Effective Speckle Noise Removal of SAR Image Based on Combination of Modified PCA and HMF with Enhancement

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***Abstract*—Despeckle of Sythetic Aperture Radar (SAR) image is a challenging task for the reseachers due to the presence of multiplicative speckle noise caused by scattered radar waves. This multiplicative speckle noise creates echoes that are directly degrades image quality, aslo makes the object identification difficult. From past few decades the number of speckles noise reduction techniques have been developed to restore the perception quality of SAR images, so that the resulting images are well suitable for further undertaking. However, the existing techniques are not able to perserve edge details of the image while reducing speckle noise. The system model proposed in this paper consists of three stages to reduce the speckle noise in the SAR image. The first stage of the proposed model consists of two stage block based modified Principal Componet Analysis (PCA) which removes maximum amount of speckle noise in SAR image. This block based modified PCA is obtain by selecting different values of standard deviation by applying certain technique that can reduce the maximum amount of speckle noise present in the SAR image. The second stage of proposed model consists of Hybrid Median Filter (HMF) that is used to further removal of the multiplicative noise remaining in the modified PCA output image, particulaly to remove the speckle noise at the edges. Final stage is used to enhance the features of the despeckle image using sharpening filter. In order to maintain good image perception quality, in this paper the selection of the standard deviation is an important factor in the proposed system model to effictively reduce the speckle noise with the existing methods. Thus the system method used in this paper produced better experimetal results than existing methods with regarding to both removal of speckle noise with enhancement of image features.**

***Index Terms*—Sythetic Aperture Radar image, Speckle noise, Despeckle image, Principal Component Analysis, Hybrid median filter.**

I. Introduction

THE Synthetic Aperture Radar is an active satellite sensor which is generally placed on a satellite or an aircraft that emits the microwave signals to remote area of interest and collect the reflected waves to form SAR image. Because of its own illumination SAR can sense remote area during both day and night in any weather conditions. SAR and optical radar images are need to be fuse in order obtain the good perception quality of remote sensing scene and to bring proper alignment of the images the co-registration process is required before the image fusion. However, SAR images are inherently degraded by a speckle noise formed by multiple interference of reflected microwaves which are scattered around the each pixel in the image. Due to presence of speckle noise in the image, the object identification is a challenging task for researchers by removing this noise and preserving good perceptional quality in the acquired SAR image. Also, this type of noise creates echoes which are directly degrades image quality, changes the precision of image registration process and reduces the significance of the merged image. Hence speckle noise reduction is prerequisites for image registration process used to align the multi sensor images geometrically. Number of speckles noise reduction techniques have been developed in the past two decades to improve the quality of SAR and optical images, so that the resulting images are suitable for further process.

Hyunho Choi et al.[1], anisotropic diffusion filter is used as a pre-processing filter for noisy image. Since speckle is a multiplicative noise, author transformed the output of pre processing image into logarithmic form to make as an additive noise. Because of additive noise Discrete Wavelet Transform (DWT) with soft thresholding and a guided filter are used to remove speckle noise by preserving edge details. The experimental results gives better performance in terms of objective and subjective than the conventional filtering method.

Younggi Byun et al. [2] , to improve the quality of SAR image, Lee Filter is used to remove speckle noise present in the homogeneous area rather than heterogeneous.

Norashikin Yahya et al. [3], homomorphic process is employed in order to transform multiplicative speckle noise image into additive noisy image, then signal and noise spaces are generated by decomposing the noisy image vector space. The clean image is obtain by removing the noise spaces and estimated from the remaining signal space using linear estimator that minimizes the image distortion. The experimental results gives better performance in terms of preservation of edges, texture, and point targets and required computational time is less.

Yao Zhao et al. [4], different sets of wavelets are used to estimate the noise level present in the SAR image. This noise level is removed based on adaptive total variation regularization by solve the total variation regularization problem. Experimental results of visual assessment of image quality and objective evaluation using Despeckle Evaluation Index (DEI) shows that Adaptive Total Variation (ATV)-regularization model preserving sharpness and edges while removing noises.

Fan YANG et al. [5] model the algorithm as a first step, is to

suppress the speckle by a pre-estimation of an image using undecimated wavelet domain with Linear Minimum Mean Square Error (LMMSE) filtering by considering as a clean image and the second step, is to perform a weighted averaging according to the similarities between the patches abstracted from clean image and original image to eliminate the influence of strong target by setting the threshold level. experimentally propose algorithm performs better than traditional methods with respect to speckle reduction and strong targets preserving.
I. Shanthi [6], Cascade form of hybrid mean and median filters combination is used to reduce the speckle noise which is a granular in nature that demean the quality of information present in the SAR. The experimental results shows better performance in terms performance metrics such as MSE and PSNR.
Zelong Wang et al. [7] a numerical algorithm is developed to improve the performance of the sparse PDE method by exploring the statistical character of speckle and the prior information of the targets on SAR images. There is a an optimal trade-off between speckle reduction and edge preserving.
Xin Wang, Linlin Ge, Xiaojing, Li [8] NEST software tool is used to remove the speckle noise which consists of four built in adaptive filters like Frost, Gamma Map, Lee, and Refined Lee filters. For varying window size, Lee gives better performance than other filters.
Gerardo Di Martino et al. [9] implementing the physical-oriented probabilistic patch-based (PPB) filter based on a priori knowledge of the underlying topography and analytical scattering models by taking the physical characteristics of the image. To de-noise the SAR images an adaptive version of the scattering-based PPB filter is used. The performance of the proposed filter gives better results in terms of speckle reduction and texture and detail preservation.
In this paper the proposed system model is divided into a three stages, first stage is used to remove the maximum amount of speckle noise present in the SAR image using two stage Principle Component Analysis (PCA). The PCA proposed in this paper is based on block of pixels and block of nearest neighbourhood pixels are considered as vector variable. This vector variable contains the training block of pixels which are selected based the local group of pixel in the image as treated local window. The various stastistical parameters are calculated for this local window so that that edge are preserved (even after applying PCA to remove the noise). The intial stage of PCA removes the maximun amout of noise present in the input SAR image and the next stage PCA steps are similar to the intial stage for futher smoothening the intial stage PCA output. Since SAR image contains multiplicative speckle noise, the two stage PCA are not able to remove the noise completly. Hence in this paper Hybrid Median Filter(HMF) is introduced in the second stage to further removal of impulse noise present at edges of two stage PCA output. However two stage system model not perserving the edges while removing the noise, becuase of this another filter is introduced as a last stage in system model to enhance the edge features of an image.

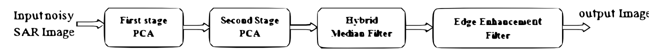

Fig. 1. Proposed system Model

II. PROPOSED MODEL

In this paper the proposed method is a combination of three different stages that are used to reduce the speckle noise in the input noisy SAR image. Fisrt Stage is two stage of Principal Component Analysis which is used to remove maximum amount of speckle noise present in input image and it smoothen the edges of entire image. Second stage is the Hybrid Median Filter which is used to remove the noise contents at the edges of the image. HMF is a class of filter which uses the linear window to preserve the details edges and lines of an image. Finally Edge sharpening filter is used to sharpen the edges which are smoothen by PCA.
The Proposed Model System is shown in fig.1

A. Block Based PCA

PCA is one of the statistical technique is used to the reduce noise in an image. PCA is orthogonal transformation which tranforms a set of correlated pixels into a set of linearly uncorrelated pixels. This transformation converts the data into a entirelly new coordinate system in such way that the highest variance of the pixel place on the first coordinate, this first pixel is called the principal component, similarly the second greatest variance of the pixel lies on the second coordinate, similarly all pixel are sorted and placed in respective coordinates. The proposed block based PCA is described as follows. The mean value of each block is calculated using (1)

$$\mu = \frac{1}{n}\sum_{i=1}^{m}\mathbf{B} \tag{1}$$

where $\mathbf{B}$ is block of an image matrix of size $m \times n$, where m and n are number of rows and colomns respectly and μ is row mean vector of size $m \times 1$.
Then zero mean of $\mathbf{B}$ is calculated using (2)

$$\mathbf{B} = \mathbf{B} - \mu \tag{2}$$

Next the covariance matrix of $\mathbf{B}$ is computed using (3)

$$\mathbf{Cov}(\mathbf{B}) = \frac{\mathbf{BB^T}}{\mathbf{n-1}} \tag{3}$$

The eigen values $\mathbf{V}$ and eigen vectors $\mathbf{P}$ of $\mathbf{Cov}(\mathbf{B})$ are calculated and sort the eigen values and arrange the eigen vectors according to the sorted eigen values. This arranged eigen vectors matrix is called as transform matrix T of size $m \times n$. Then PCA Y of each block B is calculated using (4)

$$\mathbf{Y} = \mathbf{T}^T\mathbf{B} \tag{4}$$

Next the various stastistical parameters of each block are calculated using (5)

TABLE I
HMF SUBIMAGE OF SIZE 5×5

P_d		P_r		P_d
	P_d	P_r	P_d	
P_r	P_r	P_c	P_r	P_r
	P_d	P_r	P_d	
P_d		P_r		P_d

TABLE II
SHARPENING FILTER KERNEL OF SIZE 3×3

0	-1	0
-1	5	-1
0	-1	0

$$\mu_{\mathbf{iPCA}} = \frac{\mathbf{1}}{\mathbf{n}}\sum_{\mathbf{i=1}}^{\mathbf{m}} \mathbf{Y_i} \tag{5}$$

The PCA output of each block is modified futher by selecting the different values standard deviation σ of the image using the following techniques to reduce speckle noise.
$\mathbf{S_{p_1}} = \max[\mathbf{0}, (\mu_{\mathbf{iPCA}} - \sigma^{\mathbf{2}})]$
and $\mathbf{S_{p_2}} = \mu_{\mathbf{iPCA}}./\mathbf{S_{p_1}}$.
Finally modified PCA output of each block,
$Y_{PCAoutput} = \mathbf{T}(\mathbf{Y}. * \mathbf{S_{p_2}}) + \mu_{\mathbf{i}}$ is computed.
The above mentioned procedure is continued for all blocks to get modified PCA output of complete image.

B. Hybrid Median filter(HMF)

The output of two stage PCA contains some amount of noise at the edges. This type of noise is further reduce by hybrid median filter which is non linear characterstic in nature. This filter reduces the impulse noise by perserving the edges. The table I shows 5×5 window size of subimage, where P_d represent diagonal pixels P_r represent horizontal and vertical pixels of subimage,and P_c is central pixel.

$$Median = Median(M_{P_r}, M_{P_d}, P_c) \tag{6}$$

where M_{P_d} is the median of diagonal pixels, M_{P_r} is the median of horizontal and vertical pixels with respect to the central pixel and P_c is the central pixel of 5×5 sub image. The central pixel is replace with median vaule which computed from (6). The complete HMF output is obtain by shifting 5×5 window from left to right and top to battom of entire image.

C. Enhancement of Despeckle image

The output of HMF is further enhanced by using the sharpening filter. This filter enhance the smoothen edge feature of the despeckle image. It is obtained by using the kernel shown in table II which represents the impulse response of the filter. The output of sharpening filter is obtain by shifting 3×3 kernel from left to right and top to battom along with image.
This kernel is shown in table II

III. METRICS MEASURED

The despeckle SAR output image performance is measured by the metrics like Mean value, Standard deviation, Equivalent number of looks, Root mean square error, Peak signal to noise ratio, Speckle suppression index, Speckle level reduction and mean value of ratio image.

A. Mean

The mean (μ) value of an image gives the brightness of an image pixels within that range. Mean value is required to detemine the different parameters to shift to that value. the mean value is computed using (7)

$$\mu = \frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N} x(i,j) \tag{7}$$

where $x(i,j)$ is the image, M is the number of rows, N is the number of columns.

B. Standard Deviation

Standard deviation (σ) of an image gives the variation of pixels range in an image. If variantion of pixels range is more in the image indicates that more noise present in the image and hence it determines the level of the noise. The standard deviation measured about mean value using (8)

$$\sigma = \sqrt{\frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}[x(i,j) - \mu]^2} \tag{8}$$

C. Equivalent Number of Looks (ENL)

Equivalent Number of Looks is the one of the important parametric measure used to detemine the presence of the noise level in an image. The noise variance is estimated using the equivalent number of looks (ENL). It controls the smoothing of an image, smaller ENL value indicates that more amount smoothing, a higher value of ENL indicates that more image features are preserved. If ENL is high, more speckle noise reduced in the image. The ENL is calculated using (9)

$$ENL = \left(\frac{\mu}{\sigma}\right)^2 \tag{9}$$

D. Root Mean Square Error (RMSE)

Root mean square error is the measure the amount of noise present between the input speckle and the ouput despeckle image. Lower the RMSE gives less noise present in the image.The measure RMSE is using (10)

$$RMSE = \sqrt{\frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}[x(i,j) - y(i,j)]^2} \tag{10}$$

where $x(i,j)$ is the input image and $y(i,j)$ is the output image

E. Peak Signal to Noise Ratio (PSNR)

PSNR measures the perceptional quality of the despeckle image. Higher PSNR gives the more reduction of a noise present in the output image. It computes the peak noise value of the despeckle image in terms decibels. the PSNR is calculated using (11)

$$PSNR = 20\log_{10}\frac{255}{RMSE} \tag{11}$$

F. Speckle Suppression Index (SSI)

SSI in (12) measures the performance of the proposed method used to despeckle the input image. Lower value of SSI indicates the better methods are used to despeckle the input image.

$$SSI = \frac{\sigma_o}{\mu_o} \times \frac{\mu_i}{\sigma_i} \tag{12}$$

G. Mean of Ratio Image (RI)

The characterstics of ratio image is used to determine the presence of the speckle noise. The presence of any shape or edge in the ratio image indicates that the used method is poor. If mean value of ratio image is one then the used method is good. The ratio image is computed using (13)

$$RI = I_i./I_o \tag{13}$$

Where I_i is input image and I_o is output image

H. Speckle Level Reduction (SLR)

Speckle level reduction metric indicates an amoumt of speckle noise reduced in the image. Higher the value of this metric indicates that more amount of speckle noise removed from noisy image. Speckle level variation coefficent is $C = \frac{\sigma}{\mu}$. Speckle level reduction metric is computed using (14).

$$SLR = \frac{C_i}{C_o} \tag{14}$$

Where C_i is input image speckle level variation coefficent and C_o is output image speckle level variation coefficent.

IV. Experimental Results and Discussion

The result and discussion section is divided into two parts. In first part the performance of proposed method for different noisy input images with various values of σ is discussed and different performance metrics are measured for all noisy input images. In the second part, the same noisy input image is experimently verified using various standard despeckle filters and computed the same set of metrics. The first part of discussion used three gray input noisy images of C-band and one colour image of C-band, these images are experimetally verified using proposed system model by selecting the different values of σ. Various performance metrics like standard deviation, ENL, RMSE, PSNR, SSI, mean of ratio image, speckle leval reduction etc are computed for all the input noisy SAR images.
In this paper the images used for experimental purpose are collected by the RADARSAT-2 satellite which operates at C-band with a frequency of 5.4 G hz and has spatial resolution ranges from 1 m 100 m [12]. These images provide the geographic location which includes varied terrain from the rugged mountains to the north of Vancouver, to the flat, agricultural lands of the Fraser River Delta. This setellite is an official trademark of the Canadian Space Agency and Dettwiler and Associates Ltd.(2014). It provides high resolution, SAR imagery regardless of light and weather conditions with providing coverage from 144 to 250,000 km2 in a single scene. Imaging supports single, dual and quad polarization options.

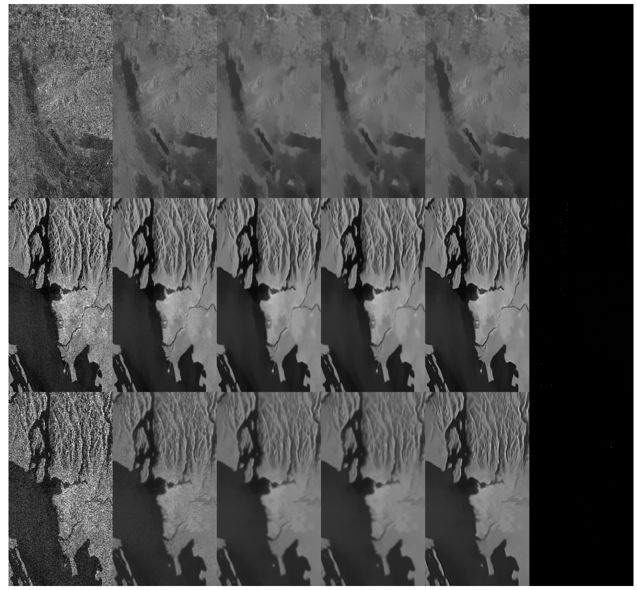

Fig. 2. Images (C-band) from left to right are noisy image, PCA1 output, PCA2 output, HMF output, Sharpen image and Ratio image for $\sigma = 60$

Fig.2 shows the three sets of selected noisy input SAR images and output images of different stages of the proposed method for $\sigma = 60$. From left to right column 1 images represent three sets of input noisy images.
Column 2 images represent first stage PCA output images which reduces maximum amount of noise present in input images. Column 3 images are second stage modified PCA output images which remove the noise present at non homogeneous area.
Column 4 images are HMF output images which reduces impulse noise at the edges.Column 5 images are system model output images which enhances the feature at edges. last column images are ratio images obtain by dividing each pixel ofthe input image with corresponding pixel ofoutput image indicate that the ratio image does not contain any details in all the three sets.

Fig.3 shows system model output images for different values σ. column 1 images are input noisy images.

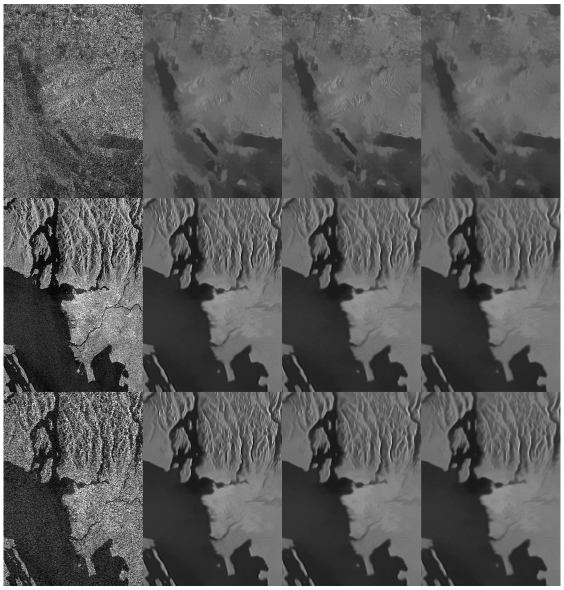

Fig. 3. Images (C-band) from left to right are noisy image, despeckel images for $\sigma = 60$, $\sigma = 70$ and $\sigma = 80$

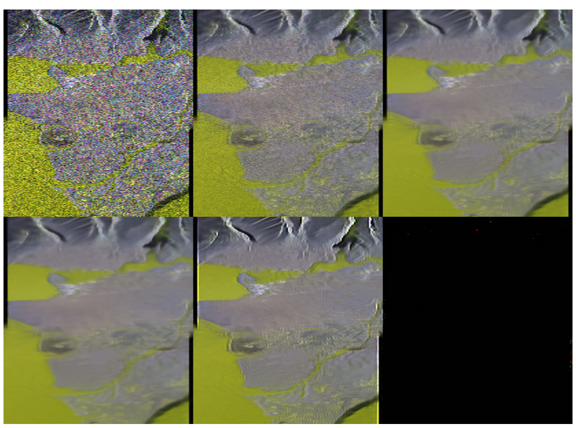

Fig. 4. Images from left to right are noisy colour (band C) image, PCA1 output, PCA2 outpur, HMF output, Sharpen image and Ratio image for $\sigma = 60$

Column 2 images are system model output images obtain by $\sigma = 60$. selecting, Column 3 images are system model output images obtain by $\sigma = 70$. selecting and Column 4 images are system model output images obtain by $\sigma = 80$. selecting.There is slight variation in the image perceptional quality between output images. Hence there is trade of between selection of standard deviation σ value and perceptional quality.

Fig.4 shows system model output images for color input image for $\sigma = 60$. Images from left to right are noisy colour input image of band C, PCA1 output, PCA2 outpur, HMF output, Sharpen image and Ratio image. From these the output images, itcan be observed that removal of speckle noise and retainting of most the structural information of the input noisy SAR image are transparent.

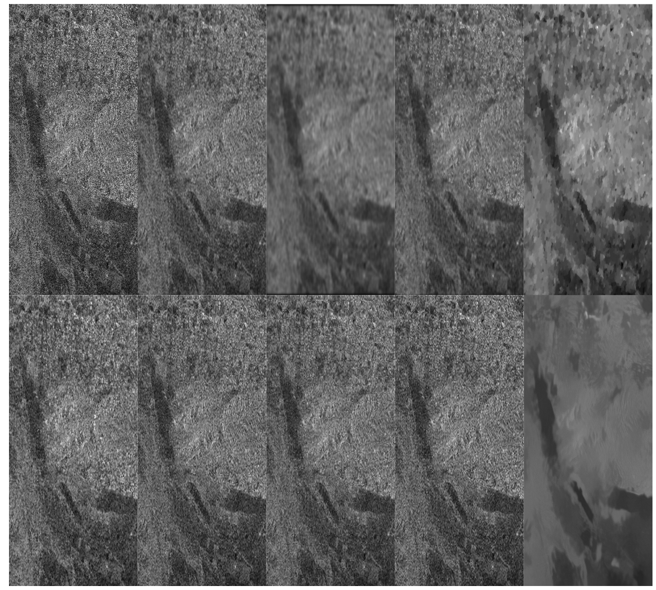

Fig. 5. Images from left to right are noisy input, Lee output, Wiener output, Homogeneous, Kaun, TV, DWT Db3, DWT haar, DWT Db6 and Prposed Method output image

Fig.5 shows original noisy image, output images of system model and the most frequently used despeckling filters such as Lee, Kuan, Wiener DWT, Homogeneous, Total variance etc . It can be observed that large amount of speckle noise is reduced by proposed method as compared to both the original image as well as output images of existing techniques. Based on the above discussion, it can be noticed that three stage of system model proposed in this paper removes maximum amount of the speckle noise present in the input noisy SAR image effectivly while perserving the edge details. Hence proposed method is consider as a good method compared to existing methods. However the required computational time for proposed method is more than existing methods.

Tables III and IV show that the experimental metrics measured with $\sigma = 60$ for different set of input noisy SAR images. From this table it observed that the proposed method results better image percepational quality even if the input noisy SAR image contain more of intensity range. Similarly Tables V, VI, VII and VIII show the performance metrics for same set of input images for $\sigma = 70$ and $\sigma = 80$ respectively. From these three tables it is noticed that the proposed method gives the better performance for higher value of σ, bacause in modified PCA stage the the selected variance is subtracted from the mean value which in turn reduces the noise. Hence as σ value increases the quality of the output image proves in the proposed method. However there is trade of between the mean and variance of input noisy SAR image in order to maintain a good percepational quality of output image. The

TABLE III
EXPERIMENTAL METRICS MEASURED FOR $\sigma = 60$

noisy images	input μ	input σ	output σ	I ENL	O ENL
1	**94.36**	**54.68**	**20.51**	**2.97**	**20.42**
2	89.41	62.35	50.01	2.05	3.12
3	114.89	61.05	37.86	3.54	9.21
4	86.35	59.85	38.96	2.08	4.76

TABLE IV
EXPERIMENTAL METRICS MEASURED FOR $\sigma = 60$

noisy images	RMSE	PSNR	SSI	RIμ	SLR
1	**48.33**	**14.44**	**0.38**	**1.00**	**2.61**
2	33.97	17.50	0.81	1.1	1.23
3	29.50	18.60	0.61	1.07	1.60
4	42.60	15.54	0.66	1.08	1.51

TABLE V
EXPERIMENTAL METRICS MEASURED FOR $\sigma = 70$

noisy images	input μ	input σ	output σ	I ENL	O ENL
1	**94.36**	**54.68**	**20.88**	**2.97**	**19.97**
2	89.41	62.35	49.02	2.05	3.23
3	114.89	61.05	39.40	3.54	8.54
4	86.35	59.85	37.48	2.08	5.09

TABLE VI
EXPERIMENTAL METRICS MEASURED FOR $\sigma = 70$

noisy images	RMSE	PSNR	SSI	RIμ	SLR
1	**47.95**	**14.51**	**0.38**	**0.99**	**2.59**
2	34.82	17.29	0.79	1.00	1.25
3	28.50	19.54	0.64	1.1	1.55
4	43.59	15.34	0.63	1.00	1.56

input image1 has highest output ENL value than other input images because it depends on homogeneous area of an image where input image1 consists of more homogeneous areas. RMSE metric measured in this paper is the noise between the input noisy SAR image and output image and indicates that input image1 contains the more noise. With this more noise the proposed method results good PSNR in dB for different input standard deviations. SSI depends on the noise level and also edges present in the input image. SSI giving the better results for input image1 in terms of noise suppression. The mean value of ratio image exactly is equal one for the input image1 that shows there is no shape or edge in the ratio image which indicates that variation is less for the proposed system model indicates that the selected method is good. The speckle level reduction obtain for input image1 is high compared to other methods indicates that more amount of speckle noise removed using the proposed method.

Tables IX and X show the compare table of different methods with proposed one with $\sigma = 80$. It is observed that the output standard deviation of proposed method is high compare to other methods, hence maximun noise is removed using the proposed method. The output ENL value for proposed method is 21.29 which is larger than all other methods, this shows that more image features are preserved. The measured value of SSI for proposed method is 0.34 which is small compared to existing techniques that shows the better method is used to despeckle the inputnoisy image. The mean value of ratio image is equal one for the proposed method that shows shape

TABLE VII
EXPERIMENTAL METRICS MEASURED FOR $\sigma = 80$

noisy images	input μ	input σ	output σ	I ENL	O ENL
1	**94.76**	**54.59**	**19.65**	**3.01**	**21.29**
2	89.41	62.35	48.40	2.05	3.30
3	114.89	61.05	36.85	3.54	9.67
4	86.35	59.85	36.56	2.00	7.09

TABLE VIII
EXPERIMENTAL METRICS MEASURED FOR $\sigma = 80$

noisy images	RMSE in dB	PSNR	SSI	RIμ	SLR
1	**48.87**	**14.34**	**0.37**	**1.00**	**2.67**
2	35.46	17.13	0.78	1.00	1.26
3	28.00	18.80	0.76	1.03	1.65
4	44.57	16.54	0.59	1.00	2.10

TABLE IX
PERFORMANCE METRICS OF VARIOUS METHODS FOR COMPARISON

Methods	input μ	input σ	output σ	I ENL	O ENL
Noisy Image	94.76	54.59	–	3.01	–
Lee	94.76	54.59	28.06	3.01	11.40
Wiener	94.76	54.59	27.48	3.01	11.84
Homogeneous	94.76	54.59	37.98	3.01	6.66
Kaun	94.76	54.59	22,29	3.01	17.78
TV	94.76	54.59	20.08	3.01	17.91
DWT Db3	94.76	54.56	33.33	3.01	8.08
DWT Haar	94.76	54.59	33.41	3.01	8.08
DWT Db6	94.76	54,59	33.47	3.01	7.99
Proposed Method	**94.76**	54.59	**19.65**	**3.01**	**21.29**

TABLE X
PERFORMANCE METRICS OF VARIOUS METHODS FOR COMPARISON

Methods	RMSE	PSNR	SSI	RIμ	SLR
Noisy Image	–	–	–	–	–
Lee	46.26	14.82	0.51	0.99	1.94
Wiener	40.90	15.89	0.50	0.97	1.98
Homogeneous	52.30	13.75	0.67	1.05	1.48
Kaun	49.70	14.20	22.29	1.04	2.41
TV	109.03	7.37	0.41	252.19	2.43
DWT Db3	56.02	13.16	0.61	1.08	1.63
DWT Haar	56.02	13.16	0.61	1.08	1.63
DWT Db6	57.63	12.91	0.61	1.11	1.62
Proposed Method	**48.87**	**14.34**	**0.37**	**1.00**	**2.67**

or edge are not present in the ratio image which indicates that the proposed method is good. The speckle level reduction obtain for the proposed method is high compared to other methods that shows more amount of speckle noise removed from input noisy image.

In the second part, the input image1 is experimentally verified using the most frequently used despeckle filters such as Lee, Kuan, wiener, Toal variation (TV), DWT etc and the same set of performance metrics are measued. Table VI Shows performance metrics of various methods are compared with the metrics of proposed method. Table III and IV show the experimental metrics measured for $\sigma = 60$ for four different noisy input images. Noisy image 1 gives the best metrics performance compared to other images by providing highest ENL of 21.42, less output image standard deviation of 20.51,mean value of ratio image of 1.00 and highest speckle level reduction of 2.61. Tables V, VI,VII and VIII give the experimental metrics measured for $\sigma = 70$ and $\sigma = 80$ respectivly for the same set of input noisy SAR images. Computed performance metrics values are good for noisy image1 with standard deviation of $\sigma = 60$.

Tables IX and X show the compare table of different methods with proposed one with $\sigma = 80$. It is observed that the output standard deviation of proposed method is high compare to other methods, hence maximun noise is removed using the proposed method. The output ENL value for proposed method is 21.29 which is larger than all other methods, this shows that more image features are preserved. The measured value of SSI for proposed method is 0.34 which is small compared to existing techniques that shows the better method is used to despeckle the inputnoisy image. The mean value of ratio image is equal one for the proposed method that shows shape or edge are not present in the ratio image which indicates that the proposed method is good. The speckle level reduction obtain for the proposed method is high compared to other methods that shows more amount of speckle noise removed from input noisy image.

V. Conclusion

In this paper the proposed system model is experimently verified for set of input noisy SAR images by selecting different values of standard deviation which playing the key role in first stage of modified PCA to reduce the maximum amount of speckle noise in the SAR image. The second stage, HMF is based on the $Median(M_{P_r}, M_{P_d}, P_c)$ of subimage of size 5×5 to reduced the impulse noise by perserving the edges. Third stage is used to enhance the features of the despeckle image and various performance metrics are measued. Also the performace of the proposed model is tested against the most frequently used despeckling filters such as Lee, Kuan, Wiener DWT, Homogeneous, Total variance etc., and same set of metrics are measured experimentaly. The experimental result shows that the performance of the proposed three stage system model is better than the existing techniques in terms of both objective and subjective by effectively removing speckles in the SAR image with perserving the edge informations. The various performance parameter metrics are measured and observed that the proposed method performs is better than existing methods in terms of metrics parameters like ENL,RMSE, PSNR, SSI, mean value of ratio image and speckle level reduction. Since the proposed system model used two stage of PCA to reduce the maximum amount of speckle noise in the input noisy SAR image it takes more computional time. So future work could be reducing the computional time and is a challenging task for reseachers.

References

[1] Hyunho Choi, Jechang Jeong, "Despeckling images using a preprocessing filter and DWT-based noise reduction techniques", IEEE Sensors Journal, Vol.18, No.8, pp.3131-3140. April 15, 2018.

[2] Younggi Byun, Jaewan Choi, Youkyung Han, " An Area-based image fusion scheme for the integration of SAR and Optical Satellite Imagery", IEEE Journal of selected topics in applied earth observations and remote sensing, Vol.6, No.5, pp. 2212-2221, October 2013.

[3] Norashikin Yahya, " Subspace-Based Technique For Speckle Noise Reduction In Sar Images ", Ieee Transactions On Geoscience And Remote Sensing, Vol.52, No.10, pp.6257- 6271 October 2014.

[4] Yao Zhao, Jian Guo Liu, " Adaptive Total Variation Regularization Based SAR Image Despeckling and Despeckling Evaluation Index ", IEEE Transactions On Geoscience And Remote Sensing, Vol.53, May 2015.

[5] Fan Yang, Ze Yu, Chunsheng L, " An Adaptive SAR Image Speckle Reduction Algorithm Based On Undecimated Wavelet Transform and Non-Local Means", IGARSS, 978-1-5090-3332-4 EEE 2016.

[6] I. Shanthi, " Speckle Noise Suppression of SAR Color Image using Hybrid Mean Median Filter ", International Journal of Computer Applications (0975 ? 8887) Volume 31 No.9, October 2011

[7] Zelong Wang , Xintong Tan, Qi Yu, Jubo Zhu," Sparse PDE for SAR image speckle suppression " Jouranals of IET Image Process., Vol.11 pp. 425-432, 2017.

[8] Xin Wang, Linlin Ge, Xiaojing, Li, "Evaluation of Filters For Envisat asar Speckle Suppression in Pasture Area", ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume I-7, 2012 XXII ISPRS Congress, 25 August - 01 September 2012, Melbourne, Australia.

[9] Gerardo Di Martino, " Scattering-Based Nonlocal Means Sar Despeckling ", Ieee Transactions On Geoscience And Remote Sensing, Vol. 54, No. 6, June 2016.

[10] M. Afonso n, J. Miguel Sanches, "Image reconstruction under multiplicative speckle noise using total variation ", Neurocomputing journal homepage: www.elsevier.com/locate/neucom

[11] Shuyaun Yang, Yueyaun Zhang, Yue Han, " Speckle reduction of SAR image through dictionary learning and point target enhancing approaches ", IEEE CIE International Conference, vol.2, pp.1926-1929, Oct. 2011.

[12] Data sets are Available: https://mdacorporation.com/geospatial/international/satellites/RADARSAT-2/sample-data